

## CHAPTER SEVEN

### PRODUCIBILITY

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## **PRODUCIBILITY**

### **OBJECTIVE**

Much attention is focused on the development of producible designs during the acquisition process. This chapter builds on a definition of producibility and its relationship to the engineering design process. Approaches to the contractual implementation of producibility provide a basis for integrating Producibility Engineering and Planning into the acquisition process. The chapter also provides a framework for evaluation of the prime contractor's producibility program and organization and a description of the Value Engineering process and its role in producibility.

### **INTRODUCTION**

Producibility is an engineering function directed toward achieving a design which is compatible with the realities of the manufacturing capability of the defense industrial base. More specifically, producibility is a measure of the relative ease of producing a product. Producibility is a coordinated effort by design engineering and manufacturing engineering to create a functional design that can be easily and economically manufactured. The product must be designed in such a manner that manufacturing methods and processes have flexibility in producing the product at the lowest cost without sacrificing function, performance, or quality. Producibility also supports the Total Quality Management (TQM) objectives by minimizing the likelihood of defects and establishing compatibility between the engineering design and the manufacturing processes.

Recently producibility, as a function, has received greater attention both in commercial industry and in defense systems programs. Department of Defense policy on major system acquisitions has made producibility considerations a requirement prior to the start of FSD, possibly as early as concept exploration validation phase if the program plans call for production. Additionally, a growing number of industrial firms have initiated formal producibility functions.

Systems design and manufacture should incorporate a structured producibility program. History has demonstrated that as the complexity of systems increases, so does the acquisition cost. Therefore, producibility programs are imperative as a management means for assuring that practicality is addressed and that the cost increases associated with the growing complexity of systems are minimized. It should be recognized that the producibility analysis accomplished by the PMO must be performed by a team of specialists assembled from the program office and supporting organizations. One functional organization cannot possibly accomplish the total producibility effort without assistance from other functional organizations. Consequently, the PMO approach to organizing for producibility is of prime importance to a successful defense system.

Basically, the program manager has responsibility for assuring that producibility is an integral consideration during the design process. Generally, the discharge of that responsibility involves the following basic elements:

- 1) Establishing producibility requirements in acquisition strategy and in system development contracts ensuring a producible design, selection of available industrial base resources, and availability of qualified production processes;
- 2) Creating support for producibility efforts throughout the entire acquisition process;
- 3) Ensuring that sufficient attention is given to technical areas involving risk and needing corrective action;
- 4) Reviewing designs for attained producibility; and
- 5) Evaluating the contractor's producibility program to ensure a continuum throughout development, production, and operational support.

While evaluating contractor's producibility program, the data and documentation demands placed on the contractor should be held to a minimum. Evaluations should make use of contractor's internally prepared information required in the execution of his producibility efforts and design review process. Specific information about requirements is discussed in succeeding paragraphs along with contractor producibility activity and approaches to the design review process. Of the five elements listed above, the program manager support of producibility may be the most critical in achieving a successful producibility program.

Generally, the prime contractor attempts to respond to all of the requirements of the contract, but the degree of emphasis and management attention is a function of the perception of the priorities of the PM. Design for producibility revolves around communication. If the contractor believes that the requirement for producibility has a very low priority, the emphasis will be minimal. In the typical system design environment, where producibility is not strongly supported, the need to create a design which meets performance goals, (within the available funding and development schedule), can motivate the contractor to structure a producibility program with form but little substance. If the beneficial effects on the design process, unit production cost and system producibility are to be realized, the program manager will need to emphasize producibility activity and be willing to allow time and funds for the accomplishment of design trade studies which are the foundation of the producibility effort.

#### RELATION TO ENGINEERING ACTIVITIES

During the creation of a design, the primary objective is to satisfy the specific functional and physical objectives established in the requirement documents. Coordination of design engineering with manufacturing engineering is effective in creating a functional design: a product designed in such a manner that manufacturing methods and processes allow for flexibility in producing the product at the lowest cost without sacrificing performance or quality. The development of a successful producibility program is dependent upon the ability of the PMO to integrate the producibility task into the mainstream of the acquisition program.

The requirement documents establish, for the designer, what the system must accomplish. These statements are the performance objectives for the system. Subsequent statements in the requirements document describe the physical, functional, and support framework for the system. These statements operate as constraints on the design. The relationships between the performance objectives and the constraints establish the potential standards of producibility for the design. If the statements of constraints rigidly specify the system, subsystem, component, materials, and manufacturing processes, the producibility of the design is essentially predetermined (even though it may not have been a primary consideration in establishing the specification). The issue of design producibility and capabilities of the production system should be specifically considered when the PMO is tailoring the system specification and other contractual requirements for the development contract.

The statement of physical characteristics for the system reflects the first constraints placed upon the designer. The statements may include the elements shown in Figure 7-1.

- **REQUIRED PHYSICAL LIMITATIONS OF THE PROPOSED SYSTEM**
  - **DIMENSIONS**
  - **WEIGHT**
  - **MAJOR ASSEMBLIES**
- **REQUIREMENTS FOR OPERATOR STATION LAYOUT**
- **INTENDED MEANS OF TRANSPORT**
- **ENVIRONMENTAL REQUIREMENTS**
  - **STORAGE**
  - **TRANSPORTATION**
  - **USE**
- **POTENTIAL EFFECTS OF EXPLOSIVES**
- **HAZARDS**
  - **BIOLOGICAL**
  - **MECHANICAL**
  - **RADIATION**
  - **OTHER**

**Figure 7-1 Physical Characteristics**

These characteristics place constraints upon the level of producibility that can be attained. (The system might, for example, be more simply designed and more easily fabricated if the weight limitations could be increased by 5%.) Regardless of the degree of complexity of an item, the objective of a balanced design is to create an item that will satisfy all of the specified performance and physical objectives and concurrently maximize producibility. Certain design practices can make a substantial contribution to attaining a high level of producibility in the system. Among these are the following:

- a) Simplicity of Design: Eliminate components of an assembly by building their function into other components or into integral components through application of unique manufacturing processes. In one case, the objective may involve working with the design engineer to identify and eliminate excess components. In another case, the focus may be on working with a manufacturing engineer to combine components.
- b) Standardization of Materials and Components: A wide variety of off-the-shelf materials and components are available. When these items are incorporated in the design, cost is generally reduced and parts availability

greatly increased.

- c) Manufacturing Process Capability Analysis: Determinations of the available manufacturing capacity, and its capability to produce the desired end item without special controls, is a critical activity in the producibility analysis. This normally includes analysis of the degree of process variability, the causes of variability and the definition of methods to reduce it.
- d) Design Flexibility: The design should offer a number of alternative materials and manufacturing processes to produce an acceptable end item. Unwarranted limitations of materials or processes seriously constrain the producibility analysis.

## CONTRACT IMPLEMENTATION

### Designing for Producibility

The contract should include specific requirements for the integration of producibility considerations into the design process. During each stage of development, an organized and systematic pattern of events must take place if a design is to meet fully all of its objectives. Implicit in these objectives is the requirement that a design achieve the highest possible degree of producibility. However, producibility goals are rarely defined in documents describing the end item.

No fixed pattern of producibility activity is applicable to all design programs. The specific sequence and nature of events must be governed by factors such as system complexity, the extent to which new processes and techniques are to be employed, the structure of the design organization, program schedule, and other variables. Even with an effective approach, the design effort must remain an iterative process in which all the principal steps must be followed if an optimized design is to be achieved. There is a substantial constraint on this iterative process in most programs because manufacturing schedules are based on a time limit on the release of the design.

As conditions depart from ideal, increasing consultation among the various specialists contributing to the design is needed. Regardless of the design structure, it is imperative that all of its special aspects be considered simultaneously throughout the entire design cycle. Only with such recurring attention can optimum results be achieved.

The design process can be modeled as sequential steps as shown in Figure 7-2. The process is not a one-pass operation but is a chain of iterative loops and interactions. With a number of possibilities to consider, analysis is required to choose the approach that shows the greatest promise. The nature of the particular problem may dictate that several approaches be developed in parallel; however, the steps remain the same. This phase requires, as a minimum, the analysis of four items: (1) risk involved in design alternatives; (2) function versus cost; (3) schedule versus cost; (4) and components required versus manufacturing capability.

Schedule is very much a producibility factor. An end item that must go into production in six months cannot use a production technique that will not be available for one year. However, a possible trade-off of a potential manufacturing development with substantial cost savings may justify rescheduling.

In analyzing components for manufacturing capability, the contractor should be considering factors such as:

1. Will the item be manufacturing in the United States or overseas?
2. Will a commercial component be available several years from now, or does the design specification greatly

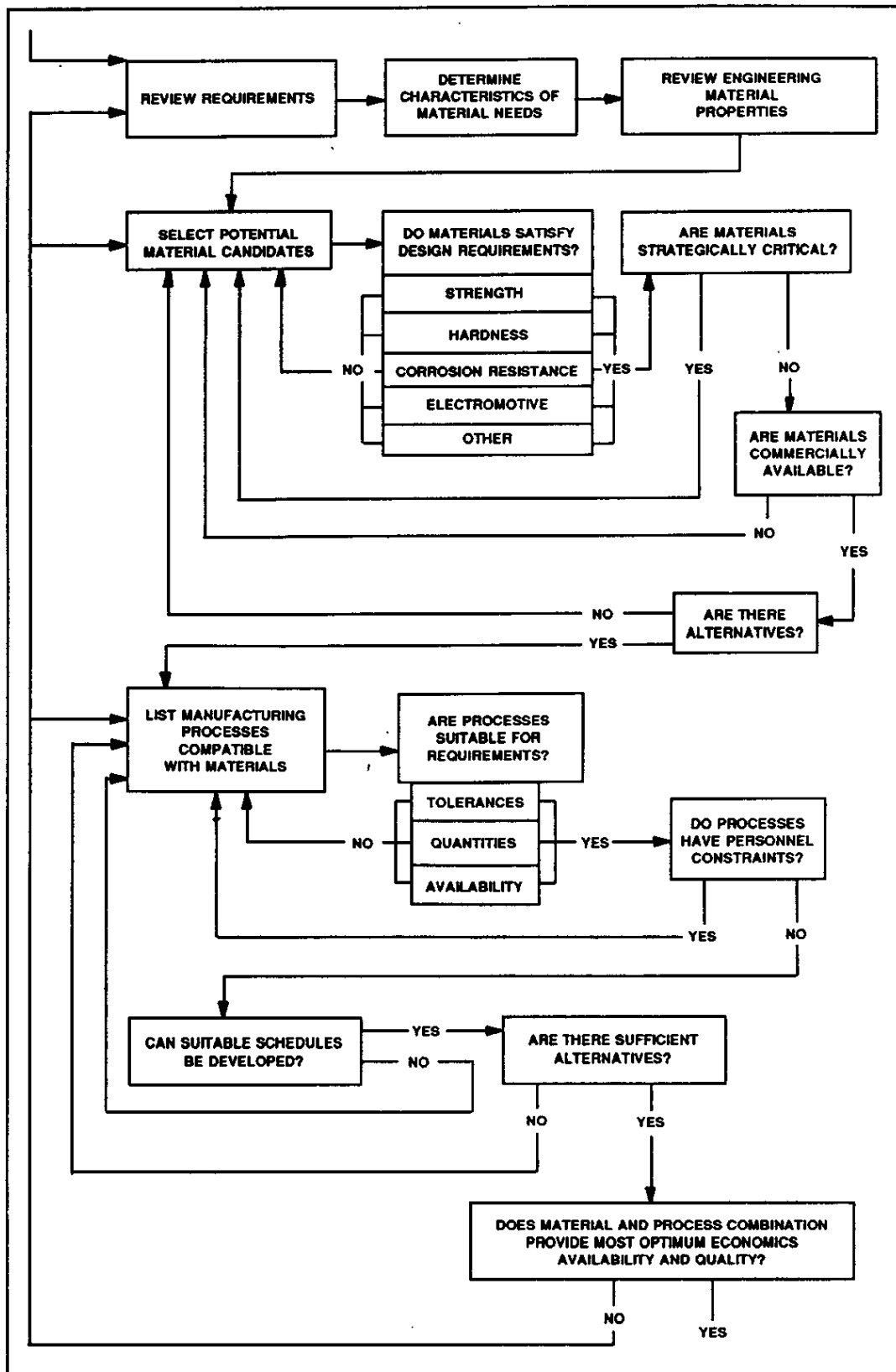


Figure 7-2 Producibility Considerations During the Iterative Design Process

limit future off-the-shelf procurement, thus reducing its cost effectiveness?

3. Is the component material on the critical list?
4. Are special tools or skills needed?
5. Have unnecessary functions and costs been eliminated?

When these preliminary analyses have been made and the approaches have been given a relative cost-effectiveness rating, the approach to be developed can be selected. Relative ratings and the peculiarities of the specific problem, schedule, funds, etc., will determine whether one or more approaches should be carried further in the design process.

Concern for producibility must be exercised at the start of the concept exploration phase and will influence the entire design effort from that point on in every item of the life cycle. Inherent producibility limitations must be recognized and addressed at each stage of the life cycle process. Broad producibility considerations might include the selection of materials and manufacturing processes. The iterative design process mapped in Figure 7-2 is filled with decision points, each of which permits a potential trade-off against some other requirement. However, all demands upon the system such as reliability, availability, maintainability, safety, or producibility heavily interact with each other throughout the design process, creating the need for trade-offs.

#### Producibility Objectives in Design

Considerations should include, but not be limited to the issues shown in Figure 7-3. Too often, it is assumed that designing for the use of existing tooling is the most economical approach, without giving due consideration to new more economical materials and processes. Further, designers also tend to design around their existing processes without due consideration to ongoing manufacturing technology developments. This can have detrimental effects on producibility which may result in excessive engineering change orders. The producibility plan discussed later in this Chapter should identify the contractor's system of review of engineering design to assure that the composite of characteristics which, when applied to equipment design and manufacturing planning, leads to the most effective and economic manufacturing approach.

MAXIMIZE	MINIMIZE
<ul style="list-style-type: none"> <li>• SIMPLICITY OF DESIGN</li> <li>• USE OF STANDARD PARTS</li> <li>• NUMBER OF POTENTIAL SUPPLIERS AND PRODUCERS</li> <li>• PROCESS REPEATABILITY AND PREDICTABILITY</li> <li>• USE OF PROVEN MANUFACTURING TECHNOLOGY AT THE SCHEDULED PRODUCTION START</li> <li>• EASE AND SPEED OF ASSEMBLY</li> <li>• USE OF ECONOMICAL MATERIALS</li> <li>• USE OF CAD/CAM</li> <li>• CONFIRMATION OF DESIGN ADEQUACY</li> </ul>	<ul style="list-style-type: none"> <li>• PROCUREMENT LEAD TIME</li> <li>• USE OF CRITICAL (STRATEGIC) MATERIALS</li> <li>• SPECIAL PRODUCTION TOOLING</li> <li>• SPECIAL TEST SYSTEMS</li> <li>• USE OF CRITICAL PROCESSES</li> <li>• SKILL LEVELS REQUIRED IN MANUFACTURING</li> <li>• UNIT COSTS</li> <li>• DESIGN CHANGES DURING MANUFACTURE</li> <li>• USE OF LIMITED CAPABILITY ITEMS AND PROCESSES</li> <li>• USE OF PROPRIETARY ITEMS WITHOUT "PRODUCTION RIGHT" RELEASES</li> <li>• REMOVAL OF EXCESSIVE MATERIAL</li> <li>• UNREALISTIC TOLERANCES</li> </ul>

**Figure 7-3 Engineering Design Criteria**

#### PRODUCIBILITY ENGINEERING AND PLANNING

The primary purpose of producibility engineering and planning (PEP) is to ensure a smooth transition from development to production. To accomplish this objective, the PEP effort must be an explicit part of the developmental activity and encompass those tasks necessary to assure weapon system or element producibility prior to quantity production. It should be noted that DODD 4245.6, "Defense Production Management," requires a contractually authorized PEP activity as part of the engineering development.

#### The Focus of Producibility Engineering and Planning

The focus of the PEP effort is evaluation of the systems design as it evolves to identify potential manufacturing problems and to suggest design trade-offs which would facilitate the manufacturing process. In order to ensure contractor availability of the necessary disciplines, such as those required to develop data packages, design special purpose production equipment and perform computer modeling or simulation of the manufacturing process from a producibility assessment standpoint, a Statement of Work (SOW) must be developed to establish both general and specific requirements.

#### Objectives and Funding

The objectives of PEP can be segregated between producibility engineering design criteria described above, and the producibility planning data requirements as shown in Figure 7-4. With approximately 60 percent of weapons system acquisition dollars expended in the production phase, it is important that the Request for Proposal for earlier program phases clearly identify the government's PEP needs. This is especially important because contractor PEP efforts will be dependent on the level of funding provided by the government in this area. Thus, the early identification of design criteria and data requirement objectives, along with the corresponding funding, will be instrumental in achieving meaningful results. Clearly, the requirements govern the level of contractor

effort. The contractual provisions, as well as corresponding Contract Data Requirements List and definitive data items, should reflect individual program needs. Special emphasis should be placed on producibility training for design, manufacturing, and quality assurance engineers. The training is likely to eliminate the chasm which often exists between these engineers. By implementing an adequately funded PEP effort early in the engineering design cycle, a strong manufacturing program will emerge.

- **MAKE OR BUY**
- **MANUFACTURING AND PROCUREMENT LEAD TIME**
- **FIRST ARTICLE LEAD TIME**
- **MANUFACTURING SCHEDULES AND DELIVERY RATES**
- **PARTS, MATERIALS, AND PROCESS PLANNING**
- **QUANTITY MANUFACTURING SKILL LEVEL REQUIREMENTS**
- **CRITICAL PATH ALTERNATIVES**
- **YIELD RATES FOR CRITICAL PROCESSES**

**Figure 7-4 Planning Data Requirements**

#### Contract Functions

The program manager should ensure that PEP objectives are identified early in the development cycle and that corresponding levels of funding will be available. As indicated by Figures 7-3 and 7-4, the SOW items establishing the PEP effort may involve many specialized contract functions and monitoring organizations. For example, in designing to meet prototype fabrication and low rate initial production schedules, special hard and soft production tooling and special test equipment requirements will normally be generated, requiring the use of attendant government property clauses. These clauses differ as a function of contract type (cost or fixed-price), degree of competition (sole-source or competitive), and category of government property. Because contractors may be influenced by factors such as desire to use contractor-peculiar capabilities and proprietary process/equipment, or to maintain a certain work force skill mix, the government's program management organization must include the flexibility to ensure focus on program goals. Government production engineers must be continuously involved with contractor design engineering in order to evaluate design proposals (such as specifications, trade-off studies and producibility analyses), configuration management, and production plans.

#### Producibility Engineering and Planning Measures

The purpose of PEP is to ensure that material designs reflect good producibility considerations prior to release for manufacture. PEP measures include the engineering tasks undertaken to ensure a timely and economic transition from development to production. PEP measures also include the confirmation of producibility during the latter stages of development. The objectives of PEP include, but are not necessarily limited to, the areas shown in Figure 7-5.

- **DEVELOP TECHNICAL DATA PACKAGES**
- **DESIGN AND PROVE OUT SPECIAL-PURPOSE MANUFACTURING EQUIPMENT AND TOOLING**
- **COMPUTER MODELING/SIMULATION**
- **ENGINEERING DRAWINGS**
- **ENGINEERING, MANUFACTURING, AND QUALITY SUPPORT INFORMATION**
- **DETAILS OF UNIQUE PROCESSES**
- **DETAILS OF PERFORMANCE RATINGS, AND DIMENSIONAL AND TOLERANCE DATA**
- **MANUFACTURING ASSEMBLY SEQUENCE METHOD SHEET SCHEMATICS**
- **MECHANICAL AND ELECTRICAL CONNECTIONS WIRING DIAGRAM**
- **MATERIAL AND FINISHING INFORMATION**
- **INSPECTION, TEST, AND EVALUATION REQUIREMENTS**
- **CALIBRATION INFORMATION**
- **QUALITY CONTROL DATA**

**Figure 7-5 Producibility Engineering Planning Objectives**

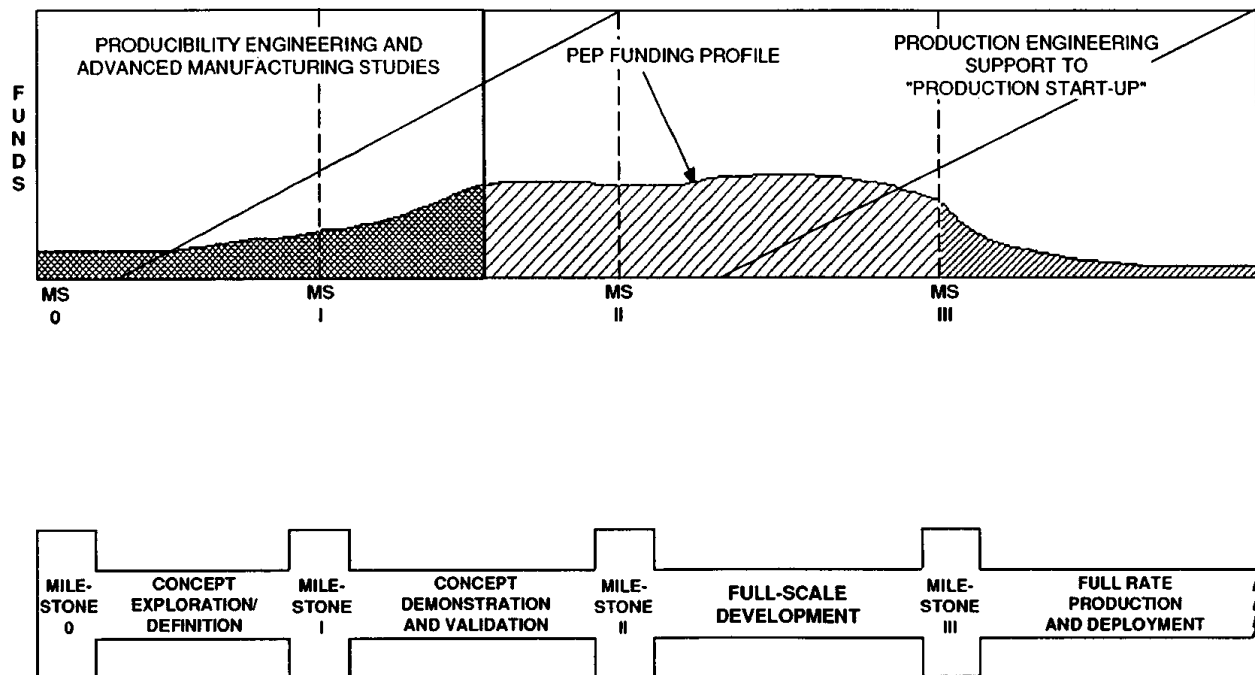
Producibility considerations can have extended horizons beyond conventional and existing production capabilities. For example, consider:

- 1) Computer modeling or simulation of manufacturing processes to assess producibility.
- 2) Performing risk analysis of new manufacturing processes.
- 3) Determining the need for manufacturing technology development efforts.
- 4) Group technology considerations in part design and fabrication plan.
- 5) Planning for new plant layouts.
- 6) Exploitation of foreign manufacturing technologies for enhanced producibility.

#### Application of Producibility Engineering and Planning in the Acquisition Process

PEP efforts are funded early enough to be essentially complete by the end of the full-scale development phase of a program. PEP should be started early in the acquisition cycle as shown in Figure 7-6 to preclude reiteration of designs resulting from changes brought about by producibility analyses. The efforts accomplished

during the full-scale development phase will primarily address producibility of critical components, and extend sufficiently into the low rate initial production phase to ensure producibility analysis of the total end item. Simultaneously, it will assure the adequacy of the technical data package. This includes changes resulting from low rate initial production.



**Figure 7-6 Producibility Engineering Planning Funding Profile**

PEP should be treated as a separate task in a research, development, test and evaluation project and should have complete visibility and traceability during the project. To ensure this visibility, the subject of producibility should be an agenda item at all program reviews and production readiness reviews.

#### Responsibility for Producibility Engineering and Planning Effort

The program manager is responsible for planning, budgeting and contractually specifying PEP efforts. The contractor is responsible for the effective execution of the PEP program. In achieving a producible design, a contractor has numerous tools available to him; however, none is more important than a well-engineered and well-executed producibility program plan.

#### PRODUCIBILITY PROGRAM PLAN

The producibility program plan details the organizational structure, authority, and responsibilities of the personnel that will be utilized to monitor producibility and perform the required analyses. Normally prepared by the contractor for the PM, the plan should outline organizational functions, methodology, objectives, and reporting procedures that will be used to ensure producibility in the design of an item. The importance of the program plan as a contractual clause cannot be overemphasized. A producibility analysis will often involve data that will require a predetermination of rights to proprietary data. Many manufacturers classify their manufacturing process information as proprietary and it is advisable to clarify this point with a contract clause on the predetermination of

rights. It must be recognized that some processes are proprietary and will remain so. It will frequently be necessary to purchase producibility engineering as a data item under a research and development contract for an end item. To assist the program office in the preparation of the data item description, the information in the following paragraphs may be helpful.

#### Data Item: Producibility Program Plan

The producibility program plan permits the determination of the manufacturer's ability to maximize the system, subsystem, and/or component producibility through the utilization of an effective organization to identify, establish, and accomplish specific producibility tests and responsibilities. This data item description is applied when the producibility task has been included in the contract statement of work.

The contractor's producibility program, which is documented in the producibility program plan, should contain (but not be limited to) these items:

1. A detailed listing of tasks and procedures used to conduct the producibility program.
2. A description of each task.
3. An identification of the unit or persons having the task assignment and their responsibility and authority.
4. An assessment of known or potential problem areas and their impact on the progress of the program.
5. A milestone planning chart or other graphic portrayal of scheduled events.
6. The plan shall provide for and schedule producibility analyses to be conducted on each design concept being considered.
7. Alternate approaches will be reported.
8. Detailed procedures and checklists for accomplishing the producibility analyses prepared for design reviews.

#### Data Item: Producibility Analysis

The producibility analysis plan permits the evaluation of manufacturer's methods of conducting the analysis to determine the most effective manufacturing methods of the end product. This data item description can be applied throughout the acquisition cycle of any program whose end result is a production program. The purpose is to assure that the systems, subsystems, and component designs meet the standards of producibility.

In establishing a requirement for producibility analyses, the PM may require the contractor to develop an appropriate set of checklists applicable throughout all the program phases. The checklists in Figure 7-7 should aid manufacturers in performing productivity analysis.

### **GENERAL ASPECTS OF DESIGN**

- a) Have alternative design concepts been considered and the simplest and most producible one selected?
- b) Does the design exceed the manufacturing state-of-the-art?
- c) Is the design conducive to the application of economic processing?
- d) Does a design already exist for the item?
- e) Does the design specify the use of proprietary items or processes?
- f) Is the item overdesigned or underdesigned?
- g) Can redesign eliminate anything?
- h) Is motion or power wasted?
- i) Can the design be simplified?
- j) Can a simpler manufacturing process be used?
- k) Can parts with slight differences be made identical?
- l) Can compromises and trade-offs be used to a greater degree?
- m) Is there a less costly part that will perform the same function?
- n) Can a part designed for other equipment be used?
- o) Can weight be reduced?
- p) Is there something similar to this design that costs less?
- q) Can the design be made to secure additional functions?
- r) Are product assurance provisions too rigorous for design or fluctuations?
- s) Can multiple parts be combined into a single net shape?
- t) Have packaging and accessibility of electronic components and assemblies been given sufficient consideration?

### **SPECIFICATIONS AND STANDARDS**

- a) Can the design be standardized to a greater degree?
- b) Can the design use standard cutting tools to a greater degree?
- c) Is there a standard part that can replace a manufactured item?
- d) Can any specifications be relaxed or eliminated?
- e) Can standard hardware be used to a greater degree?
- f) Can standard gages be used to a greater degree?
- g) Are nonstandard threads used?
- h) Can stock items be used to a greater degree?
- i) Should packaging specifications be relaxed?
- j) Are specifications and standards consistent with the planned product environment?

**Figure 7-7    Producibility Analysis Checklist**

## **DRAWINGS**

- a) Are drawings properly and completely dimensioned?
- b) Are tolerances realistic, producible, and not tighter than function requires?
- c) Are tolerances consistent with multiple manufacturing process capabilities?
- d) Is required surface roughness realistic, producible, and not better than function requires?
- e) Are forming, bending, fillet and edge radii, fits, hole sizes, reliefs, counterbores, countersinks, o-ring grooves, and cutter radii standard and consistent?
- f) Are all nuts, bolts, screws, threads, rivets, and torque requirements appropriate and proper?
- g) Have requirements for wiring clearance, tool clearance, component space, and clearance for joining connectors been met?
- h) Have all required specifications been properly invoked?
- i) Are adhesives, sealants, encapsulants, compounds, primers, composites, resins, coatings, plastics, rubber, moldings, and tubing adequate and acceptable?
- j) Has galvanic corrosion and corrosive fluid entrapment been prevented?
- k) Are welds minimal and accessible? Are the symbols correct?
- l) Have design aspects which could contribute to hydrogen embrittlement, stress corrosion, or similar conditions been avoided?
- m) Are lubricants/fluids proper?
- n) Are contamination controls of functional systems proper?
- o) Have limited life materials been identified, and can they be replaced without difficulty?
- p) Have radio frequency interference (RFI) shielding, electrical, and static bond paths been provided?
- q) Have spare connector contacts been provided?
- r) Are identification and marking schemes for maximum load pressure, thermal, nonflight items, color codes, power, and hazards on the drawings properly?
- s) Do drawings contain catch-all specifications which manufacturing personnel would find difficult to interpret?
- t) Have all possible alternatives of design configuration been shown?

**Figure 7-7 Producibility Analysis Checklist (Cont'd)**

### **INSPECTION AND TEST**

- a) Are inspection and test requirements excessive?
- b) Is special inspection equipment specified in excess of actual requirements?
- c) Is the item inspectable by the most practical method possible?
- d) Have conditions or aspects anticipated to contribute to high rejection rates been identified and remedial action initiated?
- e) Have required mock-ups and models been provided?
- f) Are special and standard test and inspection equipment on hand, calibrated, proofed, and compatible with drawing requirements?
- g) Are master and special gages complete?
- h) Have nondestructive testing techniques been implemented?
- i) Have adequate provisions been provided for the checkout, inspection, testing, or proofing of functional items per operational procedures?
- j) Is nonstandard test equipment necessary?

### **MATERIALS**

- a) Have materials been selected which exceed requirements?
- b) Will all materials be available to meet the required need dates?
- c) Have special material sizes and alternate materials been identified, sources verified, and coordination effected with necessary organizations?
- d) Do design specifications unduly restrict or prohibit use of new or alternate materials?
- e) Does the design specify peculiar shapes requiring extensive machining or special manufacturing techniques?
- f) Are specified materials difficult or impossible to fabricate economically?
- g) Are specified materials available in the necessary quantities?
- h) Is the design flexible enough so that many processes and materials may be used without functionally degrading the end item?
- i) Can a less expensive material be used?
- j) Can the number of different materials be reduced?
- k) Can a lighter gage material be used?
- l) Can another material be used that would be easier to machine?
- m) Can use of critical materials be avoided?
- n) Are alternate materials specified where possible?
- o) Are materials and alternates consistent with all planned manufacturing processes?

**Figure 7-7 Producibility Analysis Checklist (Cont'd)**

### **FABRICATION PROCESSES**

- a) Does the design involve unnecessary machining requirements?
- b) Have the proper design specifications been used as regards metal stressing, flatness, corner radii, types of casting, flanges, and other proper design standards?
- c) Does the design present unnecessary difficulties in forging, casting, machining, and other fabrication processes?
- d) Do the design specifications unduly restrict production personnel to one manufacturing process?
- e) Can parts be economically subassembled?
- f) Has provision been made for holding or gripping parts during fabrication?
- g) Is expensive special tooling and equipment required for manufacturing?
- h) Have the most economical manufacturing processes been specified?
- i) Have special handling devices or procedures been initiated to protect critical or sensitive items during fabrication and handling?
- j) Have special skills, facilities, and equipment been identified and coordinated with all affected organizations?
- k) Can parts be removed or disassembled and reassembled or reinstalled easily and without special equipment or tools?
- l) Is the design consistent with normal shop flow?
- m) Has the consideration been given to measurement difficulties in the manufacturing process?
- n) Is the equipment and tooling list complete?
- o) Are special facilities complete?
- p) Can a simpler manufacturing process be used?
- q) Have odd-size holes and radii been used?
- r) In the case of net shape processes have alternate processes been specified?
- s) Can a fastener be used to eliminate tapping?
- t) Can weld nuts be used instead of tapped holes?
- u) Can any machined surfaces be eliminated?
- v) Can roll pins be used to eliminate reaming?
- w) Do finish requirements prohibit use of economical speeds and feeds?
- x) Are processes consistent with production quantity requirements?
- y) Are alternate processes possible within design constraint?

### **JOINING METHODS**

- a) Are all parts easily accessible during joining processes?
- b) Are assembly and other joining functions difficult or impossible due to lack of space or other reasons?
- c) Can two or more parts be combined into one?
- d) Is there a newly developed or different fastener to speed assembly?
- e) Can the number of assembly hardware sizes be minimized?
- f) Can the design be changed to improve the assembly or disassembly of parts?
- g) Can the design be improved to minimize maintenance problems?
- h) Have considerations for heat-affected zones been considered when specifying a thermal joining process?

**Figure 7-7 Producibility Analysis Checklist (Cont'd)**

### **COATING MATERIALS AND METHODS**

- a) Are protective finishes properly specified?
- b) Has corrosion protection been adequately considered from the standpoint of materials, protective measures, and fabrication and assembly methods?
- c) Have special protective finish requirements been identified and solutions defined?
- d) Can any special coating or treating be eliminated?
- e) Can precoated materials be used?

### **HEAT TREATING AND CLEANING PROCESSES**

- a) Is the specified material readily machined?
- b) Are machining operations specified after heat treatment?
- c) Have all aspects of manufacturing involving heat treating and cleaning processes and their interaction with other manufacturing areas been reviewed?
- d) Are heat treatments properly specified?
- e) Are process routings consistent with manufacturing requirements (straightness, flatness, etc.)?

### **SAFETY**

- a) Have static ground requirements been implemented in the design?
- b) Have necessary safety precautions been initiated for pyrotechnic items?
- c) Have RFI requirements been implemented in the design?
- d) Have necessary safety requirements for processing materials such as magnesium and beryllium copper been considered?

### **ENVIRONMENTAL REQUIREMENTS**

- a) Have adequate provisions been included to meet the thermal, humidity, or other special environmental requirements?
- b) Has adequate heating and/or cooling been identified and implemented?
- c) Are specifications overly stringent?
- d) Can specifications be waived for unique conditions?

**Figure 7-7 Producibility Analysis Checklist (Cont'd)**

### **CONTRACTOR ORGANIZATION FOR PRODUCIBILITY**

There are a number of alternatives for the contractor when organizing to achieve producibility. Four approaches often used are:

1. Assign responsibility for the achievement of producibility to those personnel in the various existing functions as a part of their basic work tasking.

2. Assign responsibility for producibility engineering to an existing product or design engineering function. They already have responsibility for product design and consequently are in the best position to ensure producibility in the design.
3. Assign responsibility for producibility to the production or manufacturing engineering function. They are already in the best position to understand the production processes and their effect on producibility.
4. Establish a new function of producibility engineering and staff it with personnel of product engineering and manufacturing engineering background with emphasis on the latter.

Each of the listed alternatives offers some benefits and each has its limitations. Since producibility in an interdisciplinary activity, the fourth alternative is strongly favored. However, it may not be entirely suitable. Split responsibilities can be the spawning ground of management indecisiveness. A division of responsibilities for the achievement of a specific task not only impedes the ability to address the task as a whole but at the same time undermines the assignment of accountability. The specific approach to be utilized on any individual program should be dictated by the facts and circumstances of that program. It should be noted that the inclusion of the responsibility for producibility within an organization with a potentially incompatible function can result in a less than acceptable execution of the producibility responsibility. In this regard the program manager might consider the potential benefits of the contractor establishing a new function for the producibility task.

The establishment of a new function with primary responsibility for producibility engineering can take many forms: (1) it can be a completely new organization; (2) it can be a review team made up of personnel from currently assigned project functions, or; (3) it can be a permanently assigned committee made up of personnel currently assigned to functional areas. Whether the organization consists of a permanent staff, or a part-time staff, is not significant, for such organizations function in much the same manner. There is also a need, because of the accelerating advances being made on materials and processes, for an organization which allows for a close interaction between design and manufacturing.

Considering the technology explosion of recent years and the number of new processes and materials that are currently being developed, it would seem wise to bring materials specialists into the areas of manufacturing and test and evaluation, as well as specialty vendors, into the design process at an early stage. This can be done in various ways and might involve such people as process engineers, cost analysts, tool engineers, industrial engineers, quality control engineers, chemists, and metallurgists. Consequently, the form of the new organization is not important to this discussion. The main point is that detailed interaction should occur between the product design engineers and such personnel having specific knowledge of the available manufacturing technologies and their relevant costs.

### VALUE ENGINEERING

Value engineering (VE) is based on the concept that a design will cost less to manufacture if it is value engineered from its inception. However, initial product design often precedes or is accomplished independent of selection of a manufacturing system and VE then operates as a reappraisal of a design.

VE brings together all the specialized knowledge within an organization. If representatives from engineering, methods, manufacturing, and quality are brought together as a VE team activity, the value characteristics may be determined and significant benefits in cost reduction, reduced manufacturing time, and improved quality, may be realized.

### DOD Policy

DOD policy has always been to encourage value engineering because it saves money. Increasing emphasis in the 1980's led to Congressional interest in 1987 and the OMB Circular A-131 in January, 1988. Policy has shifted from DOD encouragement to OMB directed use of Value Engineering Program Requirements Clauses for contracts in initial production or research and development, unless a waiver is justified. Agencies are now

required to “actively elicit” Value Engineering Change Proposals (VECP’s) from contractors and are to emphasize VE to government and contractor personnel.

#### Elements

There are seven basic elements of the VE methodology, although they may not always be distinct and separate. In practice, they often merge or overlap. The seven elements referred to are:

1. Selection of Product — Selection of the hardware system, subsystem, or component to which VE efforts are to be applied;
2. Specification of Function — Analysis and definition of function(s) that must be performed by the hardware;
3. Collection of Information — The pulling together of all pertinent facts concerning the product; i.e., present cost, quality and reliability requirements, development history, and the like;
4. Development of Alternatives — The creation of ideas for alternatives to established design;
5. Selection of Alternatives — Estimation of the cost of alternatives and the selection of one or more of the more alternatives for testing of technical feasibility;
6. Test and Verification — Test of alternatives(s) to ensure it/they will not jeopardize fulfillment of performance (functional) requirements;
7. Submittal of Proposal and Follow-Up — Preparation and submission of a formal VE change proposal.

As an organized discipline, the VE effort should comprise all seven elements. In some contracting agencies or firms, these elements of the VE job are assigned as collateral responsibilities to design engineers, production engineers, purchasing specialists, or engineering cost analysts under the assumption that, collectively, VE efforts are being accomplished.

Another means of describing the substance of the above elements is to point out that performing the effort describes answers to the following questions about a product:

1. What is it?
2. What does it do?
3. What is it worth?
4. What does it cost?
5. What else might do the job?
6. What would that cost?

#### Value Engineering in the Contractual Environment

The objective of VE in defense contracts is to reduce the cost of acquisition and/or ownership to the government. In addition VE is also used to enhance the worth of effectiveness of the system. To accomplish these goals, special contract clauses can be utilized (FAR 48.2). These clauses can either allow or require contractors to initiate, develop and submit cost reduction proposals during the performance of the contract. Through the VE clause, the contractor is offered the opportunity to share the attained savings with the DOD.

It should be noted that a contractor-generated value VECP may be submitted, and approved by the

government, even if the contractor did not use VE techniques in developing the VECF. However, in order for a VECF to be accepted, a change to the contract must be negotiated.

#### Value Engineering Incentive Clause

The objective of this clause is to encourage contractors to develop and submit VECFs by providing for the sharing of any savings, although the contractor is not required to do VE. The clause merely describes the sharing that will take place should the contractor submit a VECF which the government accepts. Entirely permissive in intent, it allows the contractor to ignore this provision and still otherwise perform under his contract.

#### Value Engineering Program Requirement Clause

The objective of the VE program requirement clause is to reduce development, production, or use costs by requiring the contractor to establish a VE program. This clause should be used when a sustained VE effort at a predetermined level is desired. The VE program requirement is a separately priced line item in the contract and may apply to all or to selected phases of contract performance.

There are two sources of savings to be shared under the VE clauses. These are acquisition savings and collateral savings. Each will be described in the subparagraphs that follow.

#### Acquisition Savings

The FAR provides guidance on the meaning of instant, concurrent, and future contracts. For computing instant savings, the instant contract does not include supplemental agreements, options, add-ons, or other quantity modifications entered into after the VECF is approved. These savings become future acquisitions in which the contractor may share if there is such a sharing arrangement included in his contract. Prior orders are considered to be existing contracts; subsequent orders, future contracts. For multiyear contracts, the instant contract shall be the funded contract at the time the VECF is approved, and items purchased under subsequent funding under this contract shall be treated under the future contract VE sharing provisions.

In regard to computing instant cost savings and the net amount to be shared, FAR provides that the government's cost to develop and implement the change is also included in computing the net savings to be shared.

#### Collateral Savings

Collateral savings are those measurable net reductions in the cognizant military department's overall documentable projected cost of operation, maintenance, logistic support, or government furnished property (GFP) when such savings result from the VECF submitted by the contractor — whether or not there is any change in the acquisition cost. The collateral savings may be excluded from a contract or class of contracts when it is determined that the cost of computing and tracking collateral savings will exceed the benefits to be derived.